APPARATUS AND METHOD FOR SYNCHRONIZATION OF DIRECT SEQUENCE CDMA SIGNALS

This patent stems from a continuation-in-part application of U.S. patent application Ser. No. 08/450,312, filed May 25, 1995, entitled PROGRAMMABLE TWO-PART MATCHED FILTER FOR SPREAD SPECTRUM, which issued as U.S. Pat. No. 5,627,855 on May 6, 1997. The benefit of the earlier filing date of the parent patent application is claimed for common subject matter pursuant to 35 U.S.C. § 120.

BACKGROUND OF THE INVENTION

This invention relates to spread spectrum communications, and more particularly to a matched filter which can be used for synchronizing to, and despreading of, a direct sequence, spread-spectrum signal.

DESCRIPTION OF THE RELEVANT ART

Spread-spectrum communications require that an incoming spreading chip-code sequence embedded in a spread-spectrum signal, and the local spreading chip-code sequence at a receiver, be phase synchronized prior to processing of information transfer. Phase synchronization of the spreading chip code sequences is commonly known as code acquisition. Code acquisition is one of the most difficult issues facing the system designer.

Code acquisition is followed by the tracking process. Due to imperfect frequency references the incoming spreading chip-code sequence and the local spreading chip-code sequence tend to lose phase synchronization. Retaining the phase synchronization, or tracking, is a difficult process that typically employs feedback loops.

Conventional spread-spectrum systems implemented without the benefit of a matched filter employ additional circuits, such as delay locked loops (DLLs) dedicated to achieving and sustaining fine grained phase synchronization between the local spreading chip-code sequence and the incoming spreading chip-code sequence to within a unit of time which is less than the duration of one signal sample. The circuits for sustaining fine grain phase synchronization are difficult to design and implement.

In wireless environments, minimizing the performance degradation due to long or short duration attenuation of the incoming signal caused by changing propagation channel conditions is highly desirable. As the quality of the channel degrades, the quality of the detected signal degrades, often below acceptable levels.

Typical systems combat this condition by employing any of a variety of techniques collectively known as diversity processing. The diversity processing techniques have in common the ability to independently manipulate the information received through separate propagation paths, or channels, independently. The benefit from diversity processing is that when a given propagation channel degrades, the information can be recovered from signals received via other channels. A common though suboptimum, diversity technique is to employ two or more separate antennas and process the signal via two or more processing chains in parallel. Although necessary, the use of two or more antennas and processing is a difficult and costly undertaking, requiring two or more times the number of circuits required for one path as well as additional circuits and processing for insuring that the individual channel outputs are synchronized. A better approach is to employ a wideband signal of bandwidth W. If the multipath spread were T_M then the receiver can recover $L=T_M(W+1)$ replicas of the incoming signal.

If the receiver properly processes the replicas, then the receiver attains the performance of an equivalent L^{th} order diversity communication system. For wideband systems the value of L can become very large and it becomes unfeasible to implement L processing paths. Thus a non-matched filter spread spectrum receiver cannot attain the best possible performance.

The coherent demodulation of information signals requires that the phase of the carrier, at the radio frequency (RF), intermediate frequency (IF) or other frequency at which the demodulation is to take place, be known. The extraction of the phase of the carrier information requires that additional feedback loops be employed, such as phase-locked loops (PLLs), Costas loops, n^{th} power loops or other devices capable of extracting the carrier phase information. In the wireless environment, where signals propagate through a multitude of separate and independent channels, each path processed by the receiver requires its own carrier phase information and therefore its own means to extract it. This requirement greatly increases the potential complexity of the system. The need to limit system complexity acts so as to limit the system performance.

Conventional receivers, for spread-spectrum reception or other coherent systems, employ circuits dedicated to extracting the carrier phase. These techniques, e.g., phase-locked loops (PLLs), Costas loops, n^{th} power loops, etc., exhibit design and implementation complexities that are well documented throughout the professional literature. A separate and independent set of these circuits is implemented for each individual signal path, or channel, that is received. Practical limits on system complexity force the system to receive a small subset of the $L=T_M(W+1)$ independent signal replicas.

A complex matched filter consists of two identical branches, in-phase (I) and quadrature (Q), used to process in-phase and quadrature signals. Each branch has a local signal reference register, an incoming signal register, a multiplication layer and an adder tree. The multiplication layer and the adder tree contained in the in-phase and quadrature branches are identical and may contain the majority of the gates used to implement the matched filter. To implement a matched filter it is preferable to reduce the size of the structure as much as possible.

Processing multiple signals, whether quadrature-phase-shift keying (QPSK) or binary-phase-shift keying (BPSK) modulated, simultaneously by matched filtering is desirable. An example of a requirement for processing multiple signals is the simultaneous matched filter processing of the I & Q components of the BPSK or QPSK spread-spectrum signal and then combining such signals. This normally requires the implementation of two or more matched filter structures, one per signal. Matched filters are large, costly and often difficult structures to build. Thus, limiting the size and complexity of the devices as much as possible is desirable.

SUMMARY OF THE INVENTION

A general object of the invention is a spread-spectrum receiver which reduces cost and circuit complexity, reduces the volume required and improves the performance, i.e., acquisition time, of conventional spread-spectrum chip-sequence signal acquisition.

Another object of the invention is a spread-spectrum receiver which has improved bit-error-rate (BER) performance over conventional coherent demodulation techniques, methods and circuits.